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Duan et al.

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(54) **CONTINUOUSLY VARIABLE TRANSMISSION**

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CPC ... F16H 9/24; F16H 9/18; F16H 55/30; F16H 55/36; F16G 5/18; F16G 13/04; F16G 13/08
See application file for complete search history.

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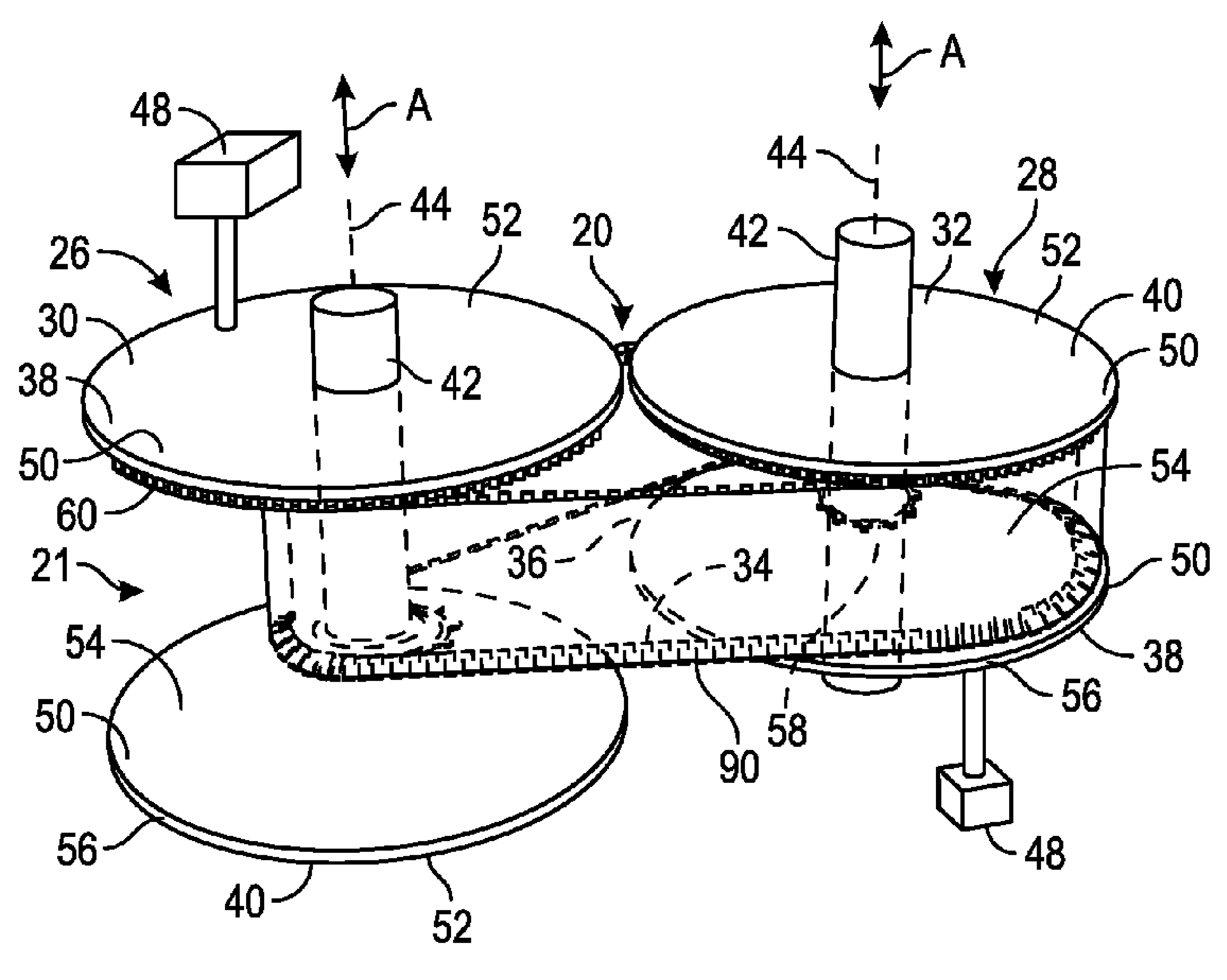
(57) **ABSTRACT**

The CVT includes a first pulley and a second pulley. Each of the first and second pulleys includes a first sheave, a second sheave, and a pulley axle operatively coupled between the first sheave and the second sheave. The first sheave can move relative to the second sheave along the pulley axle. Each of the first and second sheaves includes a sheave body and a plurality of sheave teeth protruding from the sheave body. The CVT further includes an endless rotatable device operatively coupled between the first and second pulleys. The endless rotatable device includes a plurality of pins interconnecting at least two of the links. The endless rotatable device further includes a plurality of device teeth each coupled to the pins.

17 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

F16G 13/04	(2006.01)
F16G 13/08	(2006.01)
F16H 55/30	(2006.01)
F16H 55/56	(2006.01)
F16H 9/18	(2006.01)

(52) **U.S. Cl.**

CPC ***F16H 9/18*** (2013.01); ***F16H 55/30*** (2013.01); ***F16H 55/56*** (2013.01)

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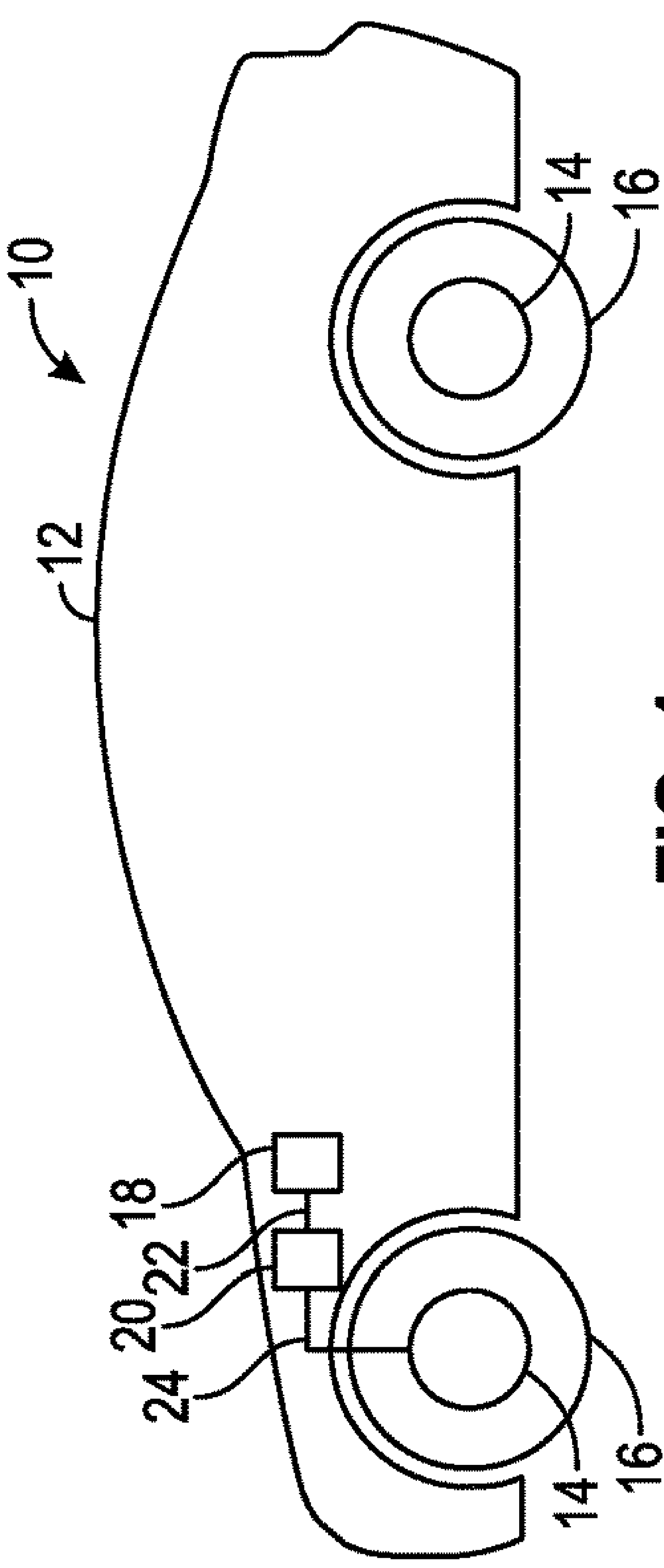

FIG. 1

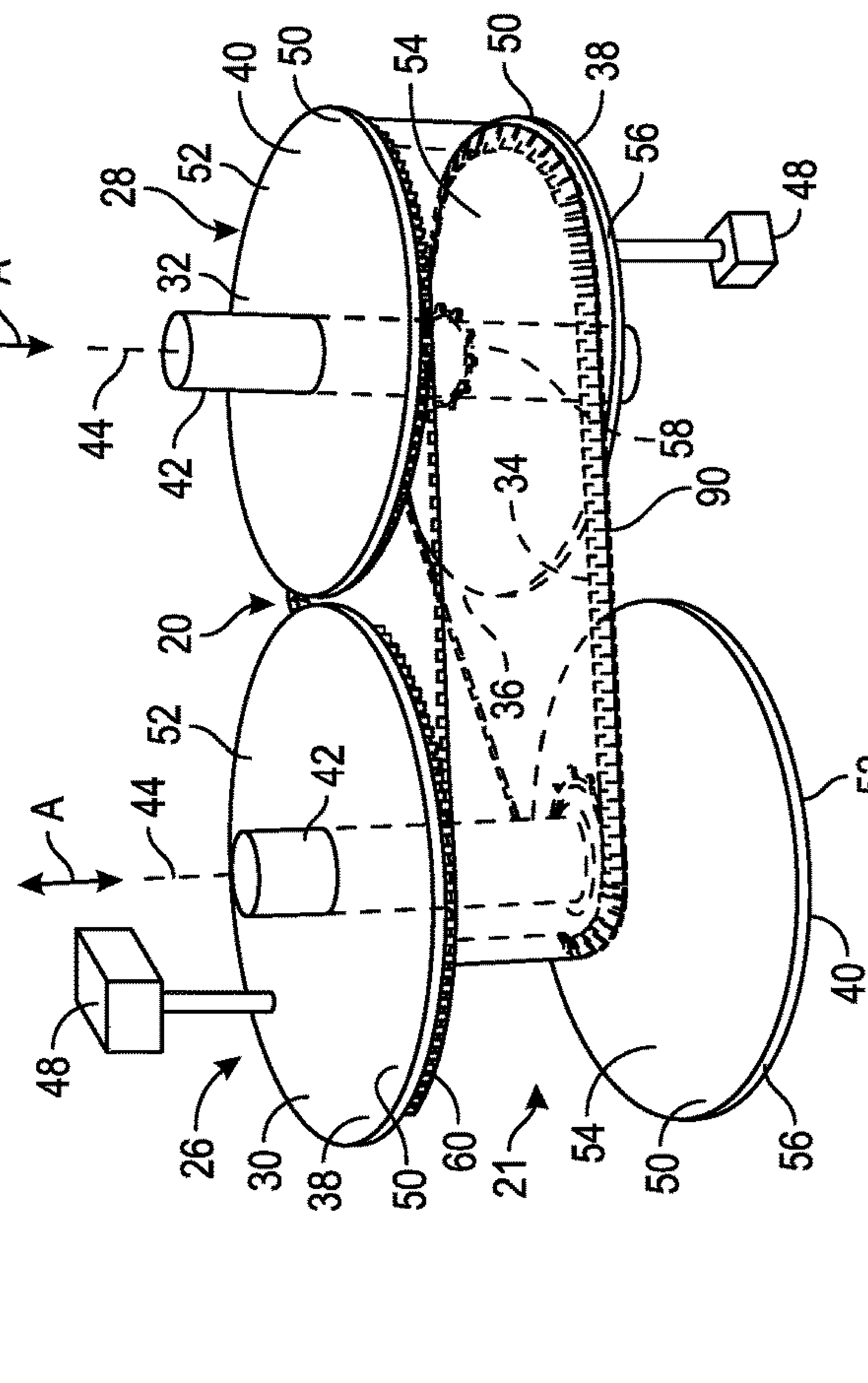

FIG. 2

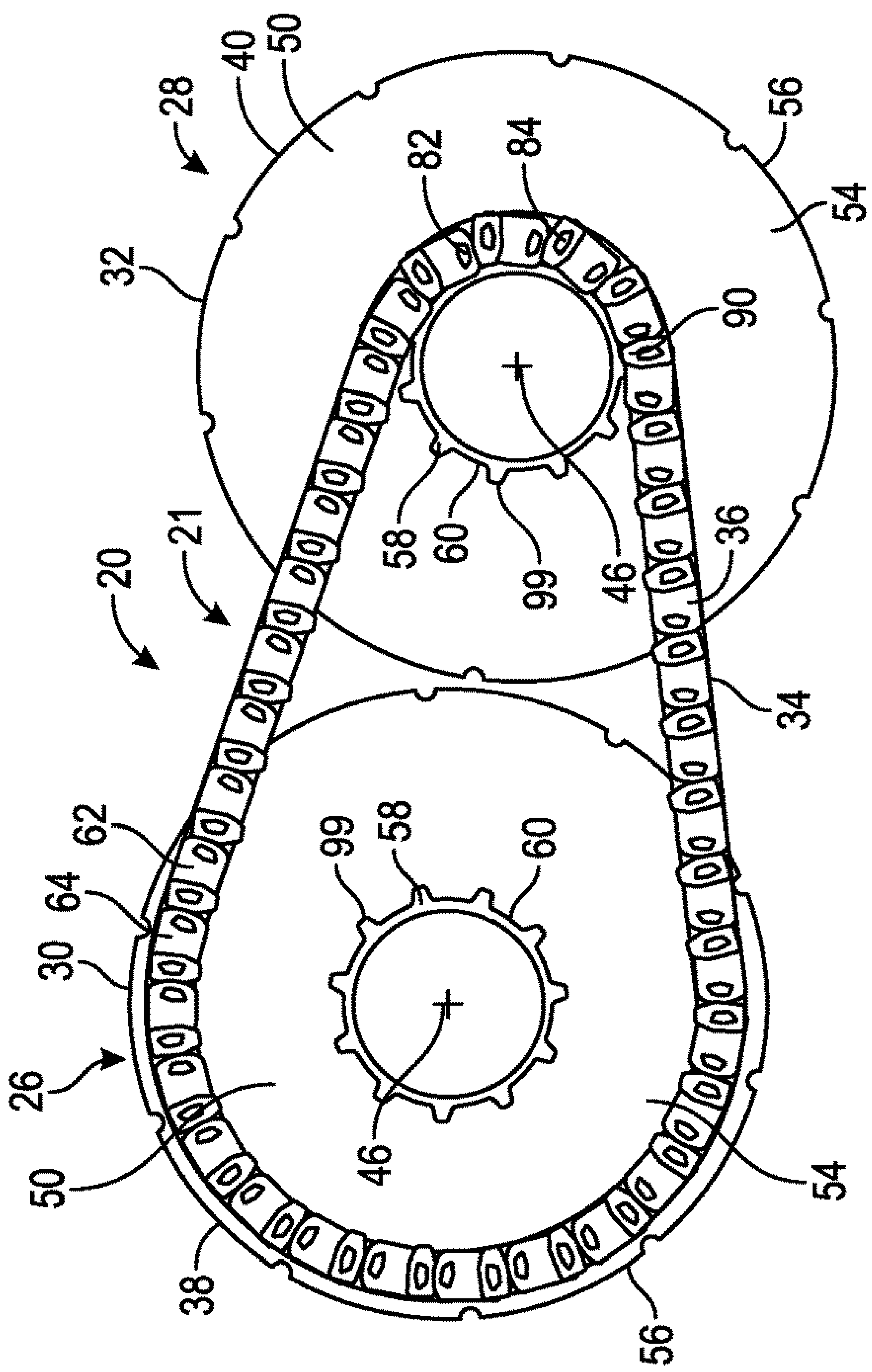

FIG. 3

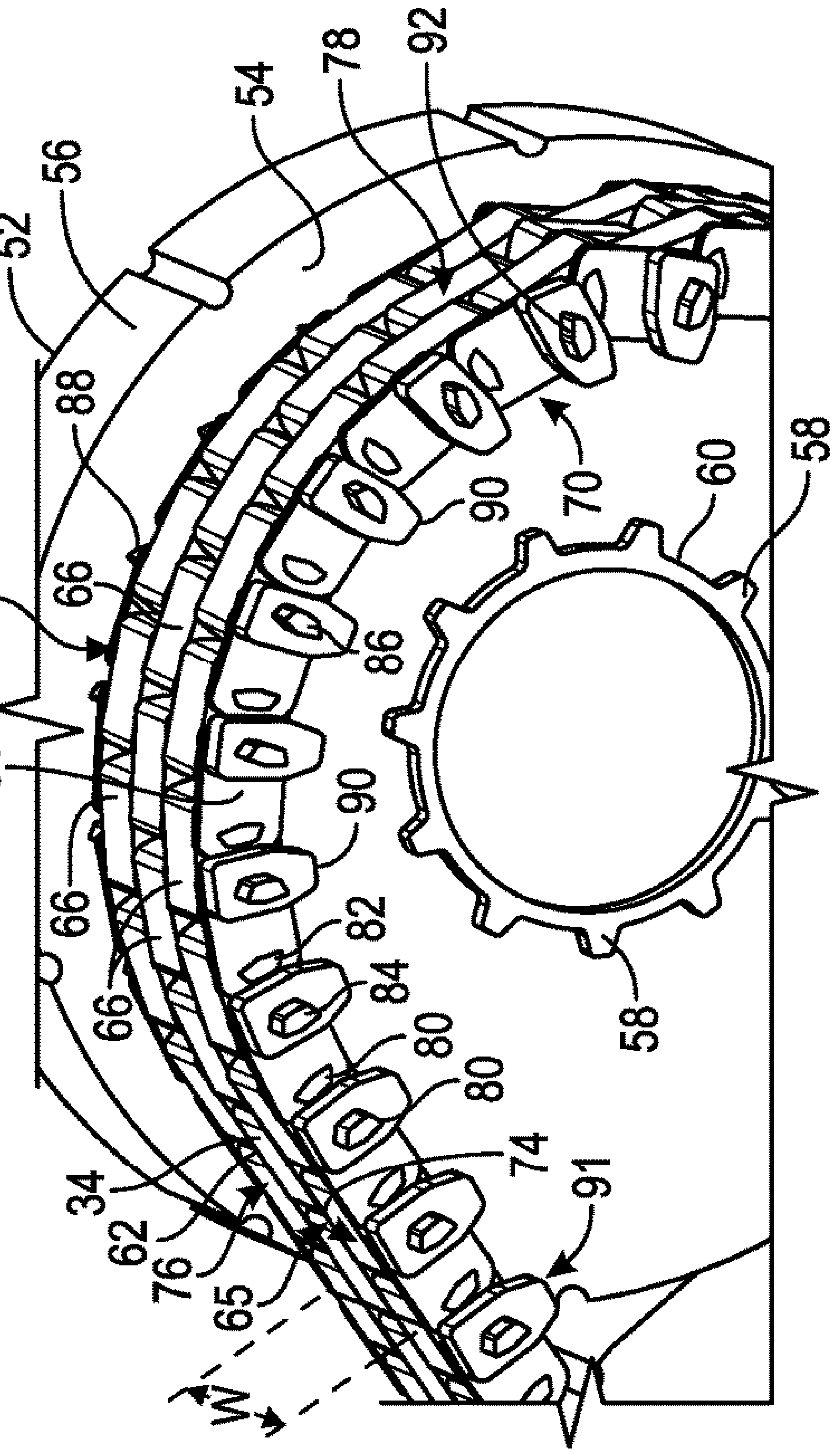

FIG. 5

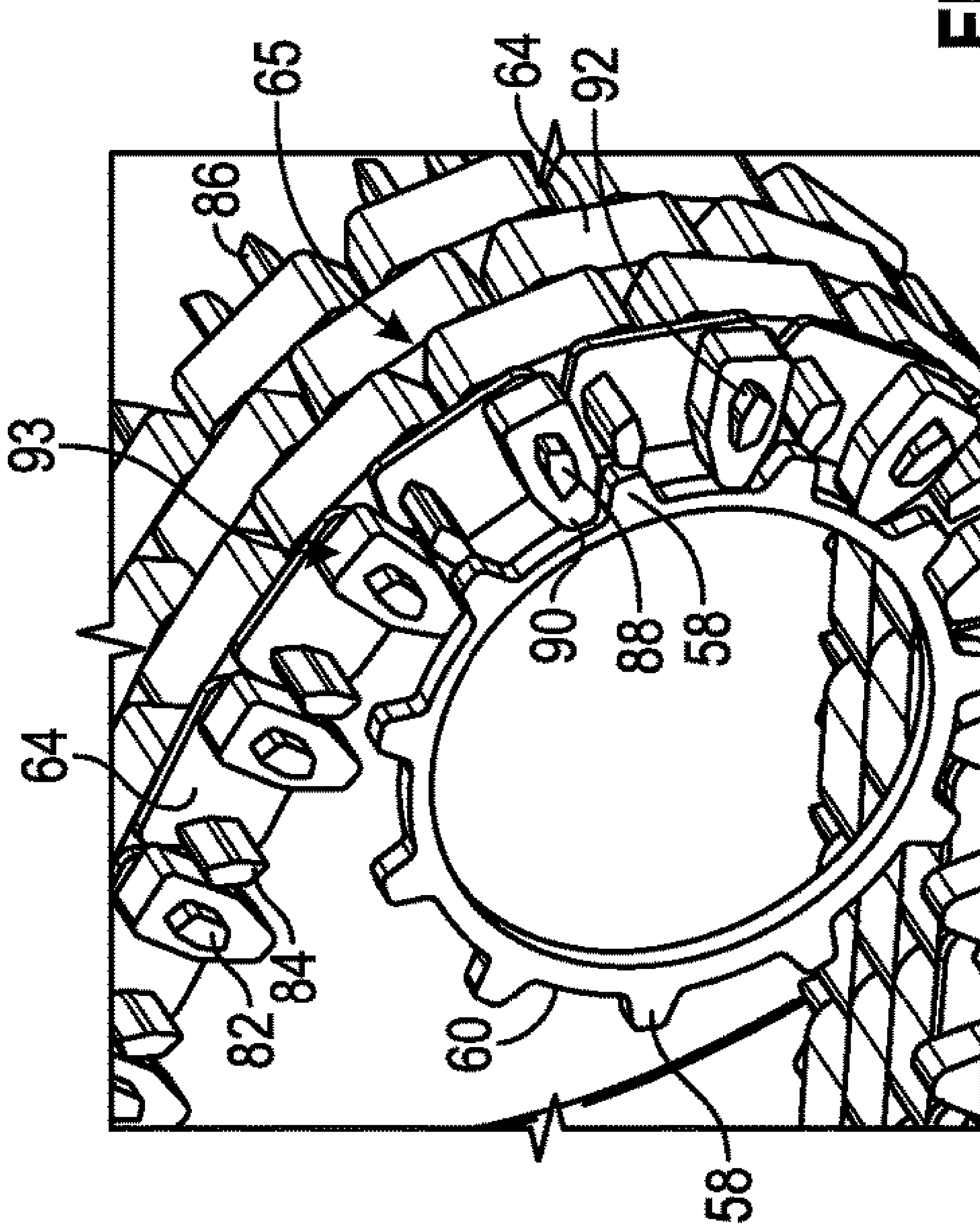

FIG. 6

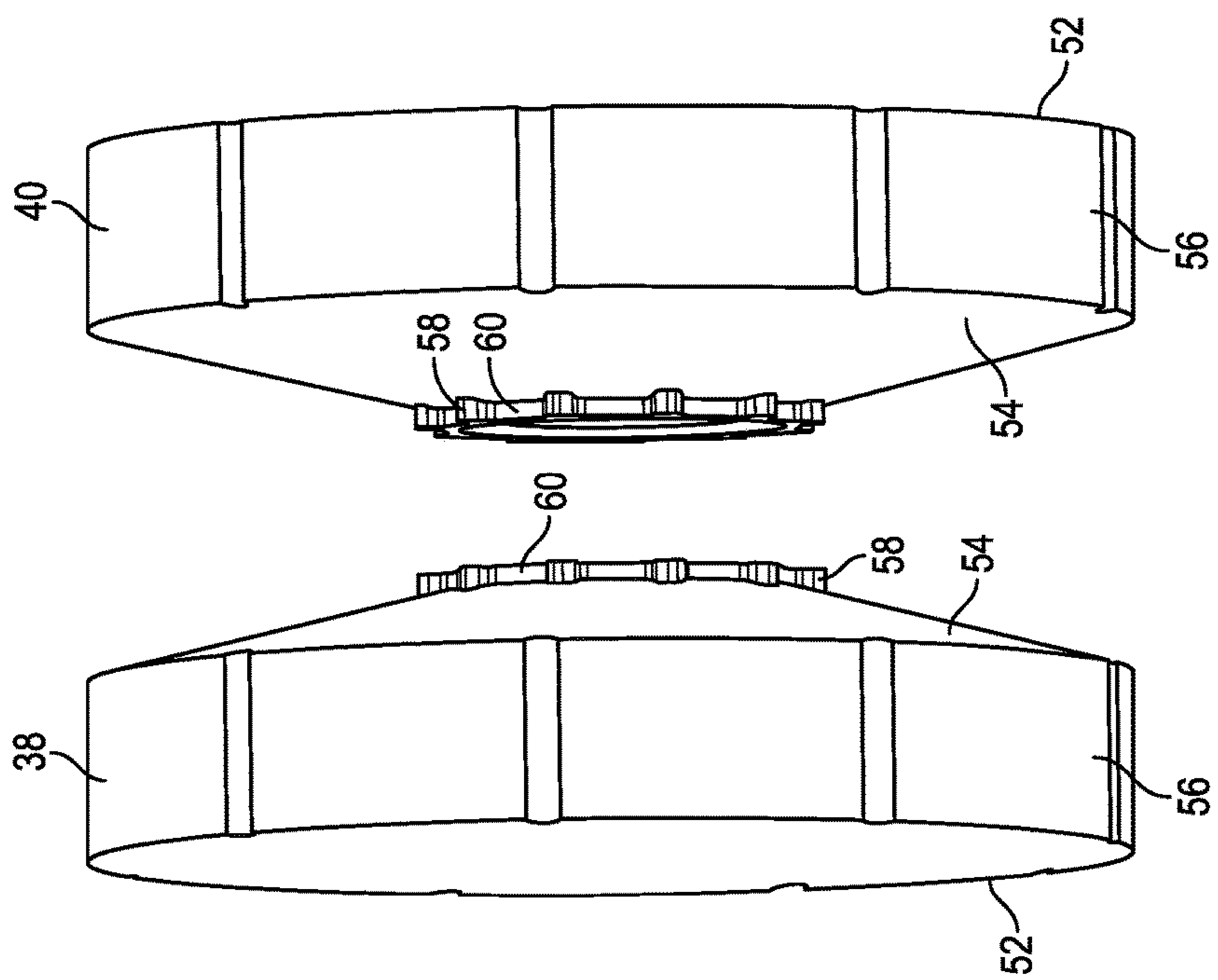

FIG. 4

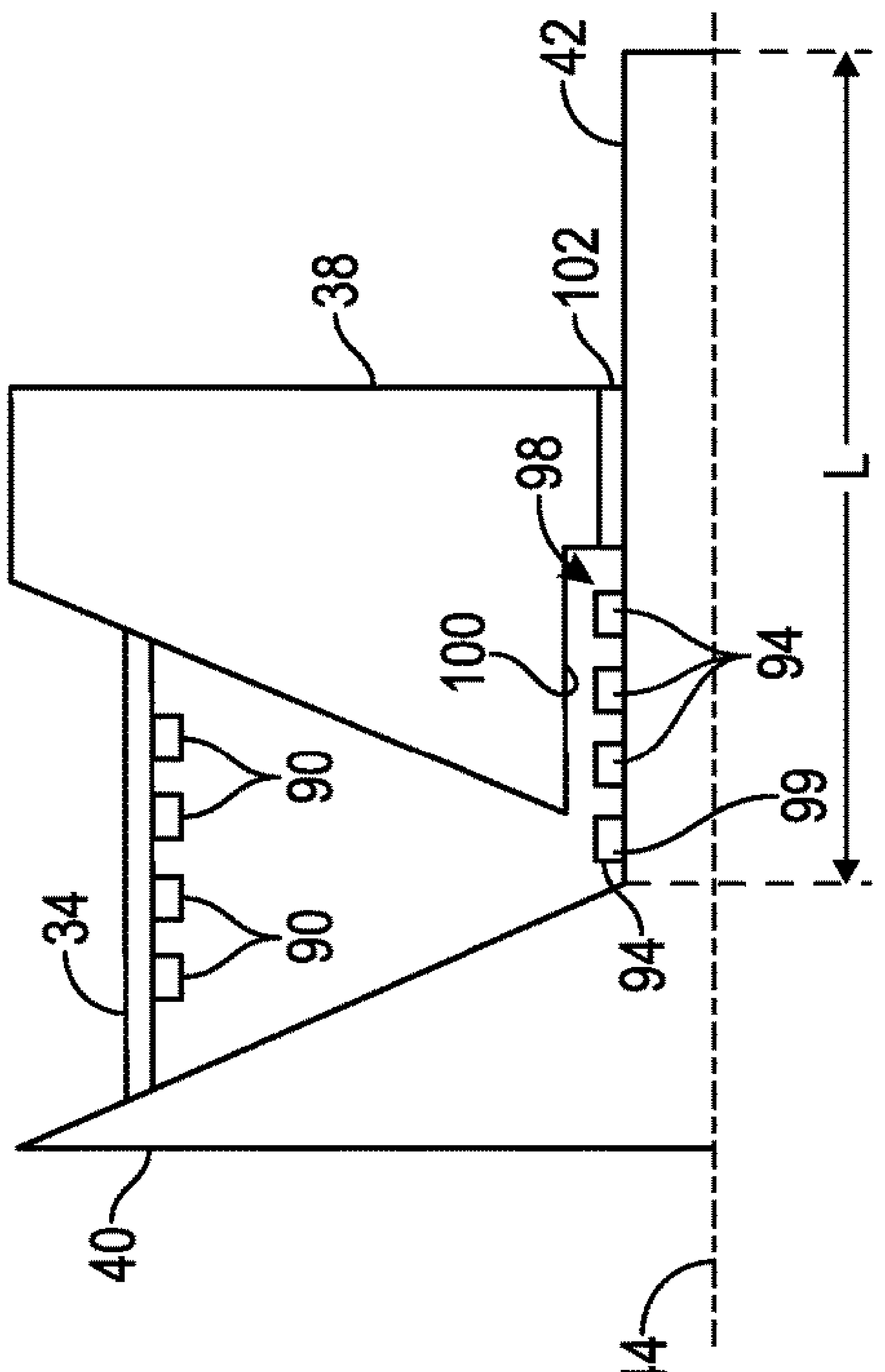

FIG. 8

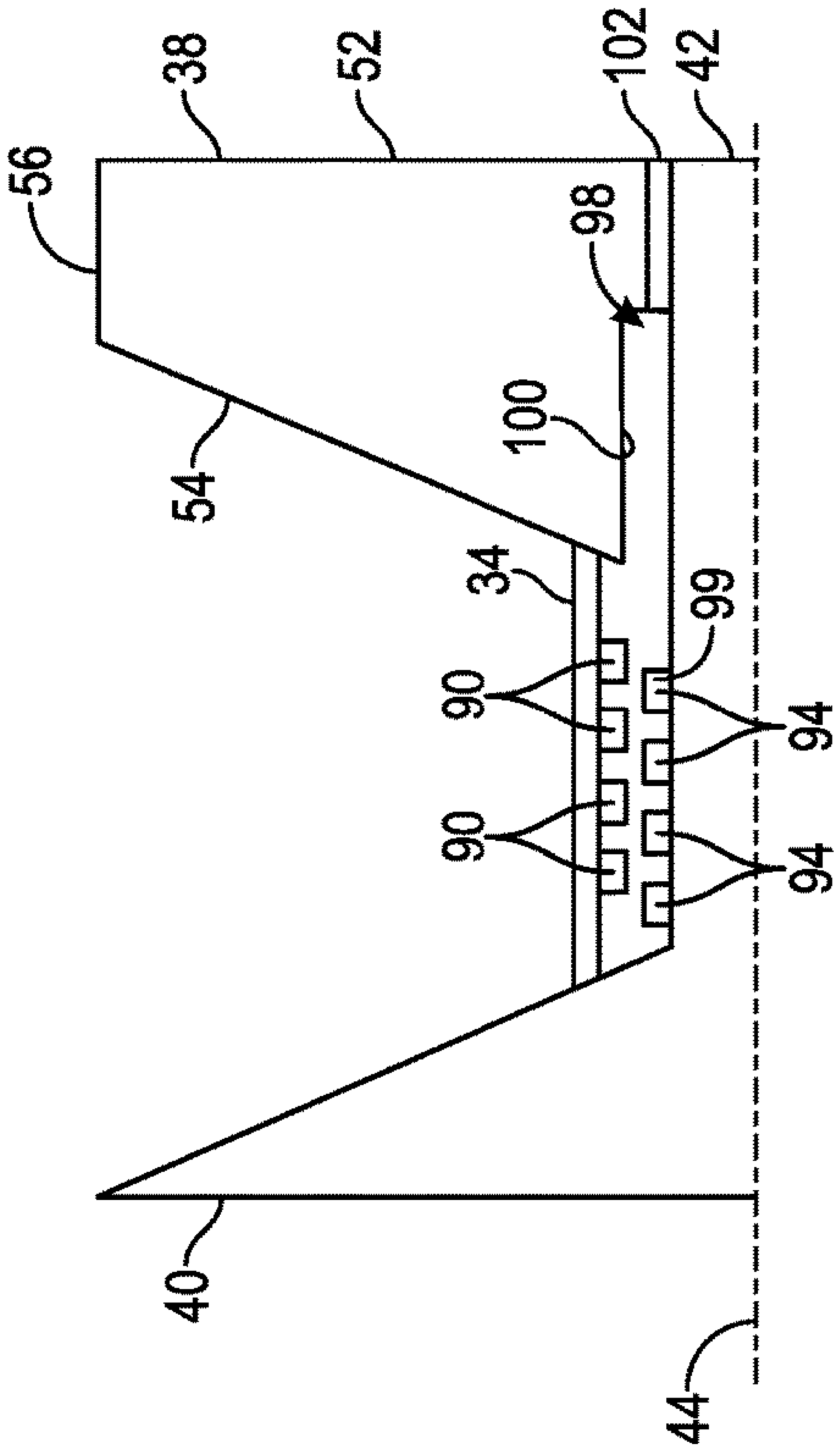

FIG. 9

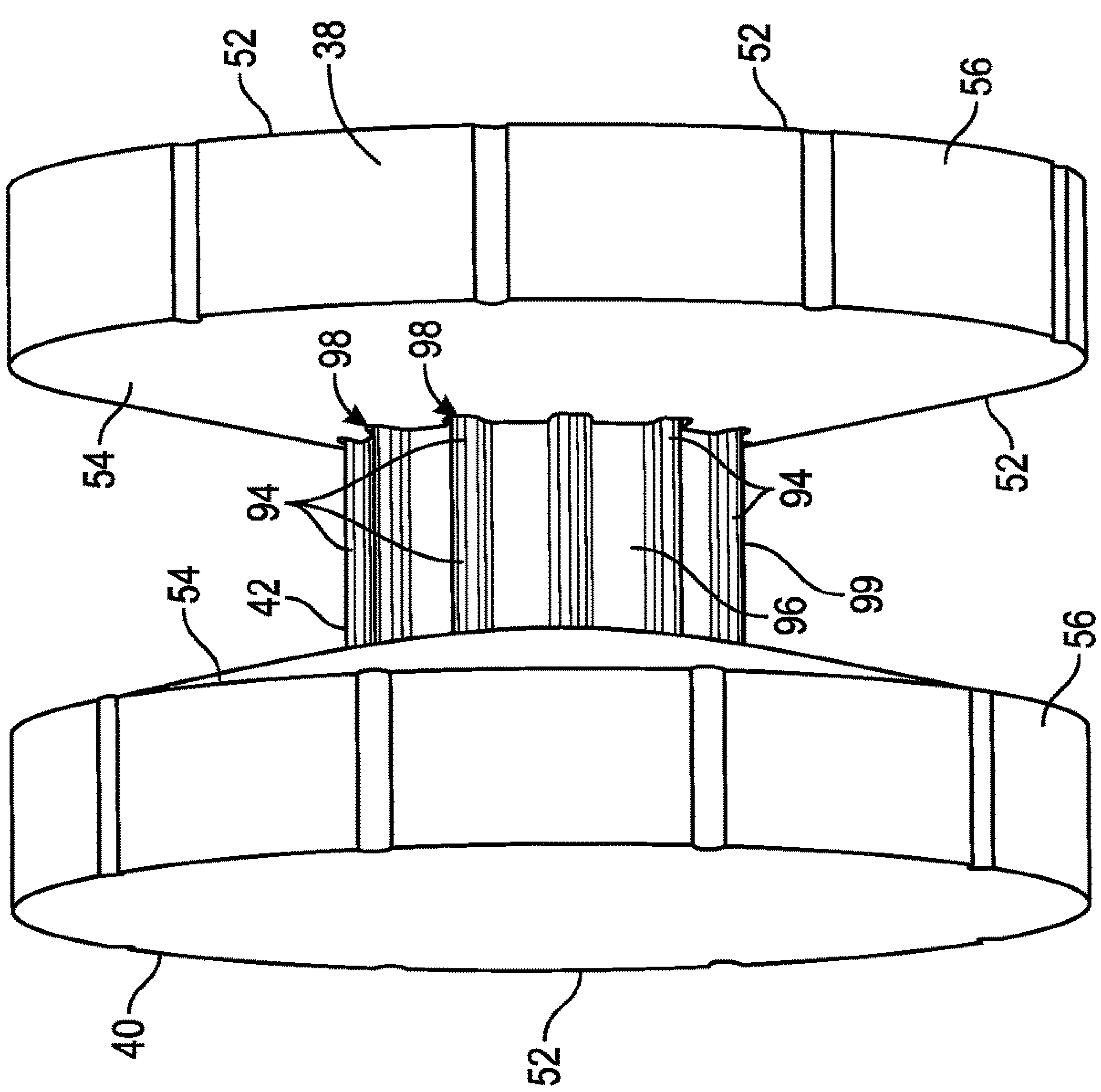

FIG. 7

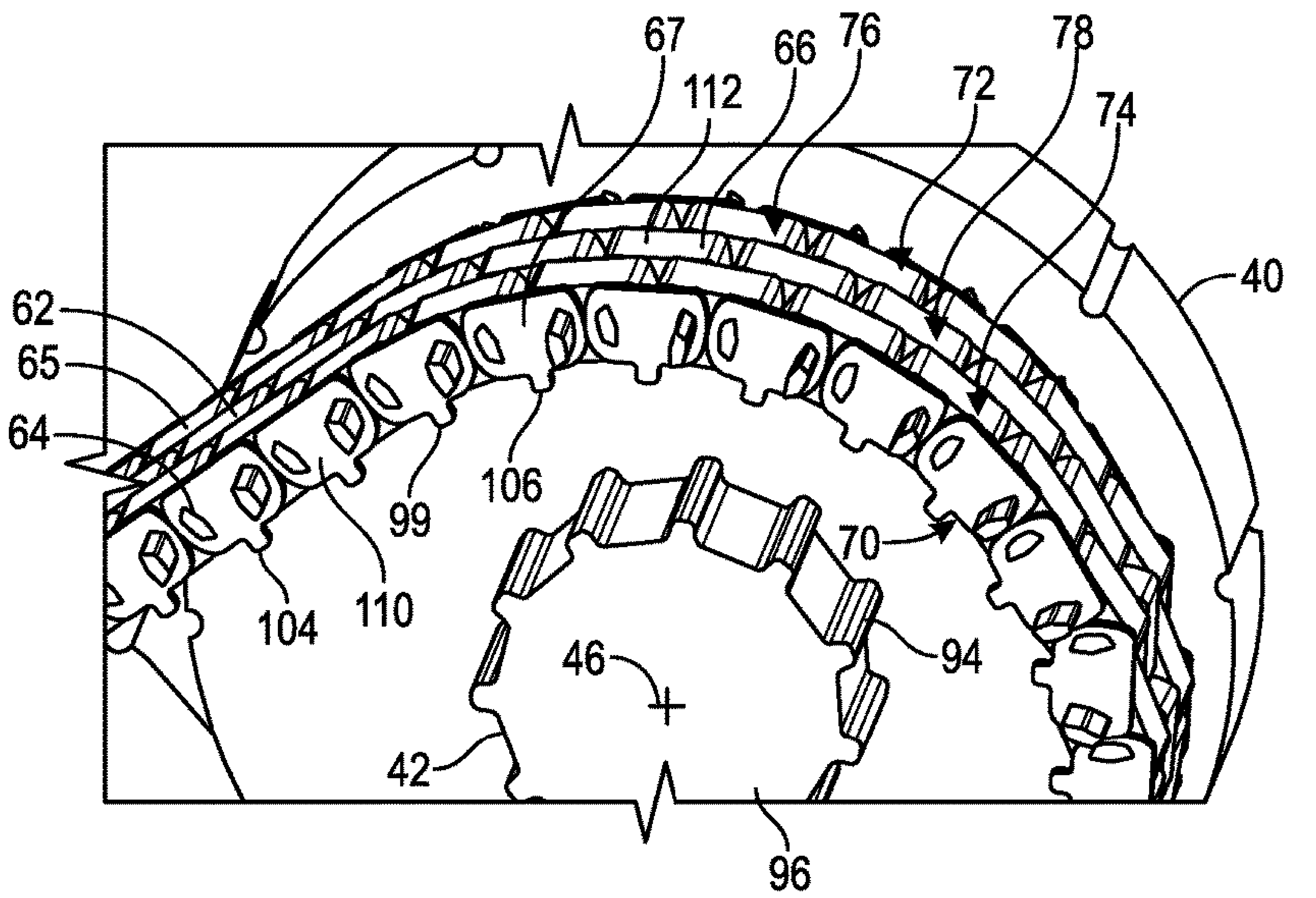
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FIG. 10

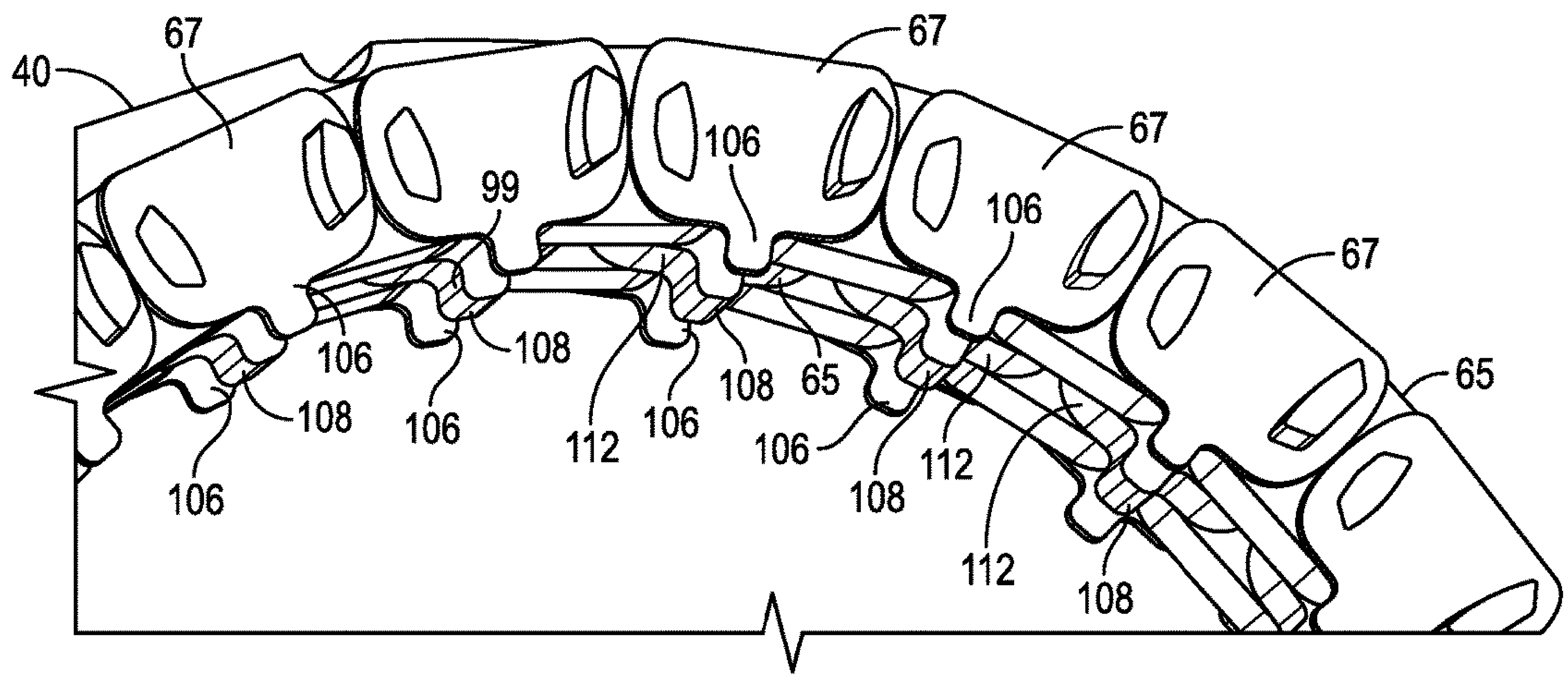
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FIG. 11

CONTINUOUSLY VARIABLE TRANSMISSION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a national phase of, and claims priority to, International Patent Application No. PCT/CN2014/092305, filed on Nov. 26, 2014, which is hereby incorporated by reference in its entirety.

INTRODUCTION

The present disclosure relates to a continuously variable transmission.

In general, a continuously variable transmission (CVT) is a transmission that can change steplessly through an infinite number of effective gear ratios between a maximum gear ratio and a minimum gear ratio. A typical continuously variable transmission includes two pulleys, each having two sheaves. A belt or any suitable endless rotatable device typically runs between the two pulleys, with the two sheaves of each of the pulleys sandwiching the belt therebetween. As used herein, the term "endless rotatable device" means a device, such as a cable or chain, without ends and capable of transferring torque when it rotates. Frictional engagement between the sheaves of each pulley and the belt couples the belt to each of the pulleys to transfer a torque from one pulley to the other. One of the pulleys may function as a drive pulley so that the other pulley can be driven by the drive pulley via the belt. The gear ratio is the ratio of the torque of the driven pulley to the torque of the drive pulley. The gear ratio may be changed by moving the two sheaves of one of the pulleys closer together and the two sheaves of the other pulley farther apart, causing the belt to ride higher or lower on the respective pulley.

SUMMARY

The present disclosure describes a CVT capable of operating several fixed speed ratios due to the positive engagement between teeth. Such operation of the CVT enhances its efficiency. In an embodiment, the CVT includes a first pulley and a second pulley. Each of the first and second pulleys includes a first sheave, a second sheave, and a pulley axle operatively coupled between the first sheave and the second sheave. The first sheave can move relative to the second sheave along the pulley axle. Each of the first and second sheaves includes a sheave body and a plurality of sheave teeth protruding from the sheave body. The CVT further includes an endless rotatable device operatively coupled between the first and second pulleys. The endless rotatable device includes a linkage assembly having a plurality of links interconnected to each other. The linkage assembly has a linkage width and includes a plurality of pins interconnecting at least two of the links. Each of the pins includes a first end portion and a second end portion opposite to the first end portion. The first end portion and/or the second end portion of the pins extend beyond the linkage width. The endless rotatable device further includes a plurality of device teeth each coupled to the first end portion and/or the second end portion of one of the pins. The device teeth are configured to engage the sheave teeth. In another embodiment, the pulley axle has an axle body and a plurality of axle teeth protruding from the axle body instead of (or in addition to) the sheave teeth. In another embodiment, the endless rotatable device includes toothed links instead of (or in addition to) the device teeth.

The above features and advantages and other features and advantages of the present teachings are readily apparent from the following detailed description of the best modes for carrying out the teachings when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic, side view of a vehicle including a CVT in accordance with an embodiment of the present disclosure;

FIG. **2** is a schematic, perspective view of the CVT schematically shown in FIG. **1**;

FIG. **3** is a schematic, front view of the CVT shown in FIG. **2**;

FIG. **4** is a schematic, perspective view of two sheaves of one of the pulleys of the CVT shown in FIG. **2**;

FIG. **5** is a schematic, perspective, fragmentary view of an endless rotatable device and a sheave of the CVT shown in FIG. **2**;

FIG. **6** is a schematic, perspective, fragmentary view of the CVT shown in FIG. **2**, depicting device teeth of the endless rotatable device positively engaged with sheave teeth of a sheave;

FIG. **7** is a schematic, perspective view of a pulley for the CVT shown in FIG. **2** in accordance with another embodiment of the present disclosure, wherein the pulley axle includes axle teeth;

FIG. **8** is a schematic, side, fragmentary view of a pulley and the endless rotatable device in an accordance with an embodiment of the present disclosure, wherein the movable sheave is disposed in a first sheave position and over the axle teeth;

FIG. **9** is a schematic, side, fragmentary view of the pulley and the endless rotatable device shown in FIG. **8**, wherein the movable sheave is disposed in a second sheave position;

FIG. **10** is a schematic, perspective, fragmentary view of a sheave and an endless rotatable device, illustrating outer links having link teeth; and

FIG. **11** is a schematic, perspective, fragmentary view of a sheave and an endless rotatable device, illustrating inner links having link teeth.

DETAILED DESCRIPTION

Referring to the drawings, wherein like reference numbers correspond to like or similar components throughout the several figures, FIG. **1** schematically illustrates a vehicle **10** including a vehicle body **12** and a plurality of wheels **14** operatively coupled to the vehicle body **12**. Each wheel **14** is coupled to a tire **16**. The vehicle **10** may be a car and additionally includes an internal combustion engine **18** and a continuously variable transmission (CVT) **20** operatively coupled to the internal combustion engine **18**. The internal combustion engine **18** can provide power to the wheels **14** in order to propel the vehicle **10**. The CVT **20** can transmit torque from the internal combustion engine **18** to the wheels **14** at different speed ratios. The CVT **20** includes an input transmission member **22**, such as a shaft, operatively coupled to the internal combustion engine **18** and an output transmission member **24**, such as a shaft, operatively coupled to the wheels **14**. In the present disclosure, the "speed ratio of the CVT" refers the ratio of the angular speed of the input transmission member **22** to the angular speed of the output transmission member **24**. Although the CVT **20** is described in connection with the vehicle **10**, it is contemplated that the CVT **20** may be used in non-automotive applications. For example, the CVT **20** may be coupled to a stationary power source such a stationary engine.

With reference to FIGS. **2-4**, the CVT **20** can transmit torque from the internal combustion engine **18** to the wheels **14** and includes a driving member **26** operatively coupled to input transmission member **22** and a driven member **28** operatively coupled to the output transmission member **24**. The driving member **26** can receive input torque from the internal combustion engine **18** via the input transmission member **22**, and the driven member **28** can transmit output torque to the wheels **14** via the output transmission member **24**. The driving member **26** may be configured as a first or input pulley **30**, and the driven member **28** may be configured as a second or output pulley **32**. The structure and operation of the first pulley **30** and the second pulley **32** may be substantially similar or identical. Accordingly, the first pulley **30** and the second pulley **32** may have the same components. In addition to the first and second pulleys **30**, **32**, the CVT **20** includes an endless rotatable device **34** capable of transferring torque. As used herein, the term "endless rotatable device" means a device, such as a belt or chain, without ends and capable of transferring torque when it rotates. In the depicted embodiment, the endless rotatable device **34** is a chain **36**. The endless rotatable device **34** (e.g. chain **36**) rotatably couples the first pulley **30** to the second pulley **32**. In other words, the endless rotatable device **34** operatively interconnects the first and second pulleys **30**, **32**. Because the endless rotatable device **34** is coupled between the first pulley **30** and the second pulley **32**, the rotation of the first pulley **30**, which is driven by the internal combustion engine **18**, causes the second pulley **32** to rotate. The endless rotatable device **34**, the first pulley **30**, and the second pulley **32** may be collectively referred to as a variator **21**.

With continued reference to FIGS. **2-4**, each of the first pulley **30** and the second pulley **32** includes a first or movable sheave **38**, a second or stationary sheave **40**, and a pulley axle **42**. The pulley axles **42** may be shafts or pins and both extend along respective pulley axes **44**. In the depicted embodiment, however, the pulley axle **42** of the first pulley **30** is rotationally coupled to the internal combustion engine **18**. Accordingly, the pulley axle **42** of the first pulley **30** can receive input torque from the internal combustion engine **18**. Rotating the pulley axle **42** about the pulley axis **44** causes the first pulley **30** and the second pulley **32** to rotate about the pulley axis **44**. Each pulley axle **42** defines a respective pulley center **46** (FIG. **3**) and is rotationally coupled between the first and second sheaves **38**, **40**. The pulley axes **44** intersect the respective pulley centers **46**. However, the pulley axis **44** of the first pulley **30** is substantially parallel to the pulley axis **44** of the second pulley **32**.

The first sheave **38** may also be referred to as the first or movable pulley portion, and the second sheave **40** may also be referred to as the second or stationary pulley portion. The first sheave **38** and the second sheave **40** may have a substantially frusto-conical shape and are both configured to rotate about their respective pulley axles **42**. However, the second sheave **40** is fixed to the corresponding pulley axle **42** and, therefore, cannot move along the corresponding pulley axis **44**. In other words, the second sheave **40** is configured to remain axially stationary relative to the pulley axis **44** defined by the pulley axle **42**. The first sheave **38**, on the other hand, can move axially along the pulley axis **44** defined by the pulley axle **42** along the direction indicated by double arrows A. Thus, the first sheave **38** can move toward and away from the second sheave **40**.

The CVT **20** further includes one or more sheave actuators **48** operatively coupled to the first pulley **30**, the second pulley **32**, or both. In the depicted embodiment, one sheave actuator **48** can apply a force to the first sheave **38** of the second pulley **32** to move the first sheave **38** toward or away from the second sheave **40** of the second pulley **32** along the direction indicated by double arrows A. Another sheave actuator **48** can apply a force to the first sheave **38** of the first pulley **30** to move the first sheave **38** toward or away from the second sheave **40** of the first pulley **30** along the direction indicated by double arrows A. Alternatively, a plate or any other suitable coupling (not shown) can interconnect the first sheaves **38** of the first pulley **30** and the second pulley **32** so that only one sheave actuator **48** is needed. In such case, the application of the force by the sheave actuator **48** to the first sheave **38** of the first pulley **30** also causes the first sheave **38** of the second pulley **32** to move relative to the pulley axis **44**.

Each of the first and second sheaves **38** and **40** has a sheave body **50** having a substantially frusto-conical shape. Each sheave body **50** defines an outer sheave surface **52** and an inner sheave surface **54** opposite the outer sheave surface **52**. The outer sheave surface **52** is substantially flat, whereas the inner sheave surface **54** is obliquely angled relative to the outer sheave surface **52** and the pulley axis **44**. The sheave body **50** additionally defines an annular lateral surface **56** interconnecting the outer sheave surface **52** and the inner sheave surface **54**.

Each of the first and second sheaves **38**, **40** further includes a plurality of sheave teeth **58** arranged annularly around the pulley center **46**. Although the drawings show that each of the first and second sheave **38**, **40** includes one set of annularly arranged sheave teeth **58**, it is contemplated that each sheave **38**, **40** may include more than one set of annularly arranged sheave teeth **58**. The sheave teeth **58** protrude from the sheave body **50**. Specifically, the sheave teeth **58** protrude from the inner sheave surface **54** in a direction away from the outer sheave surface **52** and in a direction away from the pulley center **46**. Accordingly, in this embodiment, the sheave teeth **58** remain stationary relative to the sheave (i.e., the first sheave **38** or the second sheave **40**) to which they are attached. Moreover, the sheave teeth **58** may be discrete components coupled to the sheave body **50** or may be part of the corresponding sheave **38**, **40** that are monolithically formed with the sheave body **50**.

As discussed above, the sheave teeth **58** are annularly arranged around the pulley center **46** and may be interconnected by an annular structure **60** to enhance the connection between the sheave teeth **58** and the sheave body **50**. The annular structure **60** protrudes from the sheave body **50**, and the sheave teeth **58** protrude from the annular structure **60** in a direction away from the pulley center **46**. Specifically, the annular structure **60** protrudes from the inner sheave surface **54** in a direction away from the outer sheave surface **52**.

With reference to FIGS. **3**, **5**, and **6**, the endless rotatable device **34** includes a linkage assembly **62** having a plurality of outer links **64** and inner links **66**. The outer links **64** may be chain links and may be arranged in rows. For example, the outer links **64** include a first outer row **70** of outer links **64** and a second outer row **72** of outer links **64**. The linkage assembly **62** has a linkage width W extending from the first outer row **70** of outer links **64** to the second outer row **72** of the outer links **64**. Accordingly, the first outer row **70** and second outer row **72** of outer links **64** define the outer lateral periphery of the linkage assembly **62**.

With specific reference to FIG. **5**, the inner links **66** may be chain links and are also arranged in rows. As a non-limiting example, the linkage assembly **62** includes a first inner row **74** of inner links **66**, a second inner row **76** of inner links **66**, and a third inner row **78** of inner links **66** disposed between the first inner row **74** and the second inner row **76** of inner links **66**. It is contemplated, however, that the linkage assembly **62** may include more or fewer rows of inner links **66**. Irrespective of the quantity, the inner rows (e.g., the first inner row **74**, the second inner row **76**, and the third inner row **78**) of the inner links **66** are disposed between the first outer row **70** and second outer row **72** of outer links **64**. The outer links **64** and the inner links **66** may be collectively referred to as the links **65**.

The endless rotatable device **34** further includes a plurality of pins **80** interconnecting the links **65**. Each pin **80** extends along the entire linkage width W in order to interconnect the links **65**. For example, each pin **80** interconnects at least two links **65**. In the depicted embodiment, each pin **80** can directly interconnect one outer link **64** in the first outer row **70**, one outer link **64** in the second outer row **72**, one inner link **66** in the first inner row **74**, one inner link **66** in the second inner row **76**, and one inner link **66** in the third inner row **78**. The pins **80** rotatably connect overlapping links **65**. As such, the links **65** can rotate (e.g., swing) about the pin **80**.

In the depicted embodiment, the endless rotatable device **34** includes two kinds of pins **80** (i.e., the link coupling pin **82** and the teeth coupling pins **84**). The link coupling pins **82** extend across the entire linkage width W of the linkage assembly **62** in order to couple the overlapping links **65** to each other but does not necessarily extend beyond the first outer row **70** and second outer row **72** of outer links **64**. However, as shown in FIG. **6**, the teeth coupling pins **84** may extend beyond the first outer row **70** and second outer row **72** of outer links **64**.

The teeth coupling pins **84** extend across the entire linkage width W of the linkage assembly **62** in order to couple the overlapping links **65**. In addition, the teeth coupling pins **84** extend beyond the first outer row **70** and second outer row **72** of outer links **64**. Each tooth coupling pin **84** includes a first end portion **86** and a second end portion **88** opposite the first end portion **86**. The first and second end portions **86**, **88** of the teeth coupling pins **84** extend beyond the linkage width W (i.e., beyond the first outer row **70** and second outer row **72** of outer links **64**).

The endless rotatable device **34** includes a plurality of device teeth **90** each configured, shaped, and sized to engage (e.g., mate) with the sheave teeth **58**. Consequently, the rotation of the first or second pulleys **30**, **32** causes the rotation of the endless rotatable device **34** or vice-versa. In other words, when the device teeth **90** engage (e.g., mate with) the sheave teeth **58**, rotating the first pulley **30** about its pulley axis **44** causes the endless rotatable device **34** to rotate. In turn, rotating the endless rotatable device **34** causes the second pulley **32** to rotate about its pulley axis **44**. Accordingly, the CVT **20** has a fixed speed ratio when the device teeth **90** are engaging the sheave teeth **58**. When the device teeth **90** are not engaging the sheave teeth **58**, the torque is transferred between the first and second pulleys **30**, **32** due to the friction between the endless rotatable device **34** and the first and second pulleys **30**, **32**. At this time, the sheave actuators **48** (FIG. **2**) can apply a clamping force on the first and second pulleys **30**, **32** in order to maximize the friction between the endless rotatable device **34** and the first and second pulleys **30**, **32**. However, less clamping force is needed to transfer torque between the endless rotatable device **34** and the first and second pulleys **30**, **32** when the device teeth **90** are positively engaging the sheave teeth **58** than when the device teeth **90** are not positively engaging the sheave teeth **58**. Therefore, incorporating the device teeth **90** to the endless rotatable device **34** and the sheave teeth **58** to the first and second pulleys **30**, **32** maximizes the efficiency of the variator **21**.

The device teeth **90** are directly coupled to the first end portion **86** and the second end portion **88** of the teeth coupling pins **84**. A first group **91** of device teeth **90** is coupled to the first end portion **86** of the teeth coupling pins **84**, and a second group **93** is coupled to the second end portion **88** of the teeth coupling pins **84**. In the depicted embodiment, each device tooth **90** has a pin receiving opening **92** configured, shaped, and sized to receive the first end portion **86** or the second end portion **88** of at least one tooth coupling pin **84**. The first end portion **86** (or the second end portion **88**) of the teeth coupling pins **84** extend through the pin receiving opening **92**, thereby coupling the device teeth **90** to the linkage assembly **62**. Accordingly, the device teeth **90** are outside the linkage width W and adjacent the first outer row **70** and/or second outer row **72** of outer links **64**.

During operation of the CVT **20**, the internal combustion engine **18** transmits input torque to the first pulley **30**, causing the first pulley **30** to rotate about its pulley center **46**. As the first pulley **30** rotates, the inner sheave surface **54** contacts the endless rotatable device **34**, and the friction between inner sheave surface **54** and the endless rotatable device **34** causes the endless rotatable device **34** to rotate. Because the endless rotatable device **34** is rotationally coupled to the second pulley **32**, rotating the endless rotatable device **34** causes the second pulley **32** to rotate about its pulley axis **44**. While the endless rotatable device **34** is rotating, the sheave actuators **48** may apply a force to the first sheaves **38** of the first and second pulley **30**, **32** in order to move the first sheaves **38** toward or away from the respective second sheaves **40** and in order to vary the speed ratio of the CVT **20**. As the first sheave **38** of the first or second pulley **30**, **32** moves toward the second sheave **40**, the engagement between the inner sheave surface **54** and the endless rotatable device **34** causes the endless rotatable device **34** to move away from the pulley axis **44** or pulley center **46**. Conversely, as the first sheave **38** of the first or second pulley **30**, **32** moves away from the second sheave **40**, the engagement between the inner sheave surface **54** and the endless rotatable device **34** causes the endless rotatable device **34** to move toward the pulley axis **44** or pulley center **46**. In other words, the endless rotatable device **34** is movable toward and away from the pulley center **46** as the first sheave **38** is movable toward and away from the second sheave **40**.

While the internal combustion engine **18** drives the first pulley **30**, the friction between the inner sheave surfaces **54** of the first pulley **30** drives the endless rotatable device **34**. The endless rotatable device **34** then transmits torque from the first pulley **30** to the second pulley **32**. Next, the friction between inner sheave surfaces **54** of the second pulley **32** and the endless rotatable device **34** drives the second pulley **32**. However, in addition to friction, the positive engagement between the sheave teeth **58** and the device teeth **90** may also drive the endless rotatable device **34** and the second pulley **32**.

As discussed above, the internal combustion engine **18** drives the first pulley **30**. As a result, the first pulley **30** rotates about its pulley axis **44**. While the first pulley **30** rotates about its first pulley axis **44**, the sheave actuator **48** applies a force to the first sheave **38**, thereby moving the first sheave **38** toward or away from the second sheave **40** along the pulley axis **44**. Consequently, the endless rotatable device **34** moves toward and away from the pulley axle **42**. At some point, the endless rotatable device **34** is close enough to the sheave teeth **58** such that the device teeth **90** mate with the sheave teeth **58**. When the device teeth **90** mate with the sheave teeth **58**, the positive engagement between the device teeth **90** and the sheave teeth **58** (rather than the friction between inner sheave surface **54** of the first pulley **30** and the endless rotatable device **34**) allows the first pulley **30** to transmit torque to the endless rotatable device **34**. The sheave teeth **58** may be annularly arranged around the pulley axles **42** of the first and second pulleys **30**, **32** such that the CVT **20** operates at its maximum speed ratio when the device teeth **90** mate with the sheave teeth **58** of the first pulley **30**. The operation of the CVT **20** as described above can minimize the fuel consumption of the vehicle **10**. In addition, the structure and operation of the CVT **20** as described above maximizes the capacity to transmit torque from the internal combustion engine **18** to the wheels **14** via the CVT **20**, because the CVT **20** operates at a fixed speed ratio when the device teeth **90** directly contact the sheave teeth **58**.

With reference to FIG. **7**, the device teeth **90** can directly engage (e.g., mate with) axle teeth **94** of the pulley axle **42** instead of (or in addition to) the sheave teeth **58** described above. In this embodiment, each pulley axle **42** includes an axle body **96**, and the axle teeth **94** protrude outwardly from the axle body **96** in a direction away from the pulley center **46** (FIG. **3**). The axle body **96** may be substantially cylindrical, and the axle teeth **94** are annularly arranged around the axle body **96**. In the depicted embodiment, the axle teeth **94** and the axle body **96** collectively form a one-piece structure. However, the axle teeth **94** may alternatively be configured as discrete components coupled to the axle body **96**. Regardless of their configuration, the axle teeth **94** may be substantially linear and may be elongated along the length L (FIG. **8**) of the axle body **96**. Alternatively, each axle tooth **94** may have an annular shape and extends around the circumference of the axle body **96**. Irrespective of their particular shape, the axle teeth **94** are configured, shaped, and sized to engage (e.g., mate with) the device teeth **90** in order to drive (or be driven) by the endless rotatable device **34**. The axle teeth **94** and/or the sheave teeth **58** may generally be referred to as pulley teeth **99**.

As discussed above, the first sheave **38** is axially movable relative to the second sheave **40** along the pulley axis **44**. In order to move axially without interfering with the axle teeth **94**, the first sheave **38** defines at least one recess **98** configured, shaped, and sized to receive the axle teeth **94**. In the embodiment, shown in FIG. **7**, for example, the first sheave **38** has a plurality of annularly arranged recesses **98** each configured to receive one axle tooth **94**. In the embodiment shown in FIGS. **8** and **9**, the first sheave **38** defines at least one annular shaped recess **98** configured to receive all the axle teeth **94**. Regardless of the quantity, the recesses **98** are defined by an interior sheave surface **100** that is opposite to the annular lateral surface **56**. A bearing **102** may be disposed between the pulley axle **42** and the first sheave **38** to facilitate the axial movement of the first sheave **38** relative to the pulley axle **42**.

In operation, the first sheave **38** can move toward and away from the second sheave **40** along the pulley axle **42** between a first sheave position (FIG. **8**) and a second sheave position (FIG. **9**). When the first sheave **38** is in the first sheave position relative to the second sheave **40**, the first sheave **38** is disposed over at least some of axle teeth **94** and the recess **98** receives the axle teeth **94**. When the first sheave **38** is in the second sheave position relative to the second sheave **40**, the first sheave **38** does not necessarily overlap the axle teeth **94** and the recess **98** does not necessarily receive the axle teeth **94**.

With reference to FIGS. **10** and **11**, the linkage assembly **62** may include link teeth **104** instead of (or in addition to) the device teeth **90** (FIG. **5**). The link teeth **104** are configured, shaped, and sized to engage (e.g., mate with) the axle teeth **94** and/or the sheave teeth **58**. The link teeth **104** may be part of some or all the outer links **64** disposed along the first outer row **70** and/or the second outer row **72**. Alternatively or additionally, the link teeth **104** may be part of some or all the inner links **66**. Accordingly, the link teeth **104** may include outer link teeth **106** and/or inner link teeth **108**.

With specific reference to FIG. **11**, at least some of the inner links **66** include an inner link body **112** and an inner link tooth **108** protruding from the inner link body **112** in a direction toward the pulley center **46** (FIG. **10**). Each inner link tooth **108** is configured, shaped, and sized to engage (e.g., mate with) the axle teeth **94** and/or the sheave teeth **58**. In the depicted embodiment, only the inner links **66** disposed along the third inner row **78** (FIG. **10**) include inner link teeth **108** in order to minimize costs. Specifically, all the inner links **66** disposed along the third inner row **78** include inner link teeth **108**. However, it is contemplated that more or fewer inner links **66** may include inner link teeth **108**. For example, all the inner links **66** may include inner link teeth **108**. The links **65** (i.e., outer links **64** and/or the inner links **66**) that include link teeth **104** are referred to as toothed links **67**. Accordingly, each toothed link **67** includes at least one link tooth **104**.

While the best modes for carrying out the teachings have been described in detail, those familiar with the art to which this disclosure relates will recognize various alternative designs and embodiments for practicing the teachings within the scope of the appended claims. Furthermore, the embodiments shown in the drawings or the characteristics of various embodiments mentioned in the present description are not necessarily to be understood as embodiments independent of each other. Rather, it is possible that each of the characteristics described in one of the examples of an embodiment can be combined with one or a plurality of other desired characteristics from other embodiments, resulting in other embodiments not described in words or by reference to the drawings. Accordingly, such other embodiments fall within the framework of the scope of the appended claims.

The invention claimed is:

1. A continuously variable transmission (CVT), comprising:

a first pulley;

a second pulley;

wherein each of the first and second pulleys includes:

a first sheave;

a second sheave;

a pulley axle operatively coupled between the first sheave and the second sheave, the first sheave being movable relative to the second sheave along the pulley axle,

wherein each of the first and second sheaves includes:

a sheave body; and

a plurality of sheave teeth protruding from the sheave body;

an endless rotatable device operatively coupled between the first and second pulleys, wherein the endless rotatable device includes:

a linkage assembly including a plurality of links, wherein the linkage assembly has a linkage width;

a plurality of pins interconnecting at least two of the plurality of links, wherein each of the pins includes a first end portion and a second end portion opposite the first end portion, and at least one of the first end portion and the second end portion extends beyond the linkage width; and

a plurality of device teeth each coupled to at least one of the first end portion and the second end portion of one of the plurality of pins, wherein the device teeth are configured to engage the sheave teeth;

wherein a first group of the device teeth are directly coupled to the first end portion of the pins, and a second group of the device teeth are directly coupled to the second end portion of the pins.

2. The CVT of claim **1**, wherein the pulley axle defines a pulley center, and the sheave teeth are arranged annularly about the pulley center.

3. The CVT of claim **2**, wherein each of the first and second sheaves includes an annular structure directly coupled to the sheave teeth.

4. The CVT of claim **3**, wherein the sheave teeth protrude from the annular structure.

5. The CVT of claim **4**, wherein the sheave teeth protrude from the annular structure away from the pulley center.

6. The CVT of claim **5**, wherein each of the first and second sheaves defines an outer sheave surface and an inner sheave surface opposite the outer sheave surface, wherein the annular structure protrudes from the inner sheave surface away from the outer sheave surface.

7. The CVT of claim **1**, wherein the first and second end portions extend beyond the linkage width.

8. A continuously variable transmission (CVT), comprising:

a first pulley;

a second pulley;

wherein each of the first and second pulleys includes:

a first sheave;

a second sheave;

a pulley axle operatively coupled between the first sheave and the second sheave, the first sheave being movable relative to the second sheave along the pulley axle, wherein the pulley axle includes:

an axle body; and

a plurality of axle teeth protruding from the axle body, the plurality of axle teeth being annularly arranged around the axle body;

an endless rotatable device operatively coupled between the first and second pulleys, wherein the endless rotatable device includes:

a linkage assembly including a plurality of links, wherein the linkage assembly has a linkage width;

a plurality of pins interconnecting at least two of the plurality of links, wherein each of the pins includes a first end portion and a second end portion opposite the first end portion, and at least one of the first end portion and the second end portion extends beyond the linkage width; and

a plurality of device teeth each coupled to at least one of the first end portion and the second end portion of one of the plurality of pins, wherein the device teeth are configured to engage the axle teeth;

wherein a first group of the device teeth are directly coupled to the first end portion of the pins, and a second group of the device teeth are directly coupled to the second end portion of the pins.

9. The CVT of claim **8**, wherein the axle teeth extend along a length of the pulley axle.

10. The CVT of claim **8**, wherein the first sheave defines an annular lateral surface and an interior sheave surface opposite the annular lateral surface, the interior sheave surface defines at least one recess, and the at least one recess is sized to receive the axle teeth.

11. The CVT of claim **10**, wherein the first sheave is movable relative to the second sheave along the pulley axle between a first sheave position and a second sheave position, and the at least one recess receives the axle teeth when the first sheave is in the first sheave position.

12. The CVT of claim **11**, wherein the at least one recess does not receive the axle teeth when the first sheave is in the second sheave position.

13. The CVT of claim **8**, wherein the pulley axle defines a pulley center, and the axle teeth are arranged annularly about the pulley center.

14. A continuously variable transmission (CVT), comprising:

a first pulley;

a second pulley, wherein each of the first and second pulleys includes pulley teeth;

wherein each of the first and second pulleys includes:

a first sheave;

a second sheave;

a pulley axle operatively coupled between the first sheave and the second sheave, wherein the first sheave is movable relative to the second sheave along the pulley axle; and

an endless rotatable device operatively coupled between the first and second pulleys, wherein the endless rotatable device includes:

a plurality of links interconnected to each other, wherein the plurality of links includes:

a plurality of toothed links including link teeth, wherein the link teeth are configured to engage the pulley teeth;

wherein endless rotatable device includes a linkage assembly formed by the plurality of links, the linkage assembly has a linkage width, and the plurality of links includes outer links arranged along a first outer row and a second outer row, and the linkage width extends from the first outer row to the second outer row;

wherein the plurality of links includes inner links disposed between the first outer row and the second outer row of outer links, the inner links are arranged along a first inner row, a second inner row, and a third inner row disposed between the first inner row and second inner row, and the toothed links include the inner links arranged along the third inner row.

15. The CVT of claim **14**, wherein the toothed links include the outer links arranged along the first outer row and the second outer row.

16. The CVT of claim **15**, wherein the plurality of links includes inner links disposed between the first outer row and the second outer row, and toothed links include the inner links.

17. The CVT of claim **14**, wherein the plurality of links includes inner links disposed between the first outer row and the second outer row of outer links, and the inner links are arranged along at least one inner row disposed between the first outer row and the second outer row of outer links, and the toothed links include the inner links.

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